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Surveys of the distribution of seabirds found in the vicinity of proposed geothermal project subzones in the district of Puna, Hawai'i

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INTRODUCTION

In 1993, the U.S. Fish and Wildlife Service (USFWS) entered into an interagency agreement with the Department of Energy (DOE) to conduct specific biological surveys to identify potential impacts of the proposed geothermal development on the natural resources of the East Rift Zone (Figure 1). This report presents information from published literature information and new field data on seabird populations on the island of Hawai`i. These data are analyzed with regard to potential impacts of geothermal development on seabird populations in this area.

Fifteen species of seabirds, waterbirds, and shorebirds are documented or suspected of being found using habitats within or immediately adjacent to the three geothermal subzones located in the Puna district on the island of Hawai`i (Table 1). Of these species, two are on the federal Endangered Species List, three are on the State of Hawai`i Endangered Species List, and all 15 are protected by the federal Migratory Bird Act.

SPECIES POTENTIALLY FOUND WITHIN THE STUDY AREA

Newell's shearwater or A`o (*Puffinus puffinus newelli*):

The Newell's shearwater (Newell's) is a medium sized shearwater 30 to 36 cm long with white underparts and black crown, neck, back, wings and tail. The sharply hooked bill is black but sometimes has a brown tint. The webs of the feet are pink and the toes are gray, with well-developed claws (Pratt *et al.* 1987; USFWS 1983). Taxonomists have debated the classification of the Newell's since its discovery in 1894. The USFWS considers the Newell's a subspecies of the Manx shearwater (USFWS 1983). The Newell's shearwater was believed to have gone extinct sometime after 1894. However in 1954, a specimen was collected on Oahu (King and Gould 1967) and a breeding colony was found on Kaua`i in 1967 (Sincock and Swedberg 1969). In 1975 the Newell's was listed as threatened (USFWS 1983). As of 1993, fourteen colonies have been discovered on Kaua`i (Ainley and Podolsky 1993), and more are believed to exist. Remnant populations may still be nesting on the Kohala and Hamakua coasts and in the Puna district on the island of Hawai`i (Banko 1980a; Hall 1978; Kepler *et al.* 1979).

A summary of the Hawai`i Forest Bird Survey (Jacobi 1985) notes that no shearwaters were recorded in the Puna district, but they are known to nest in wet forest habitats, typical of the East Rift Zone with a likely nesting colony in Maka`opuhi Crater. A partly burned carcass and an egg were discovered after a volcanic eruption at Maka`opuhi Crater in Hawai`i Volcanoes National Park (HVNP) in August of 1972 (Banko 1980a). Banko heard Newell's calls at the crater the next month.

Other reports of Newell's shearwaters in Puna District have been documented. Two Newell's were seen offshore at Kalapana in April 1970. In August of 1975, birds were observed off the coast of Harry K. Brown Park and near the Waha`ula Visitors Center and Kamoamoa in HVNP (Banko 1980a).

Newell's shearwater typically nests colonially in sloped terrain between 150-700 meters (500-2300 feet) elevation (USFWS 1983). Newell's dig burrows and nest underground in areas associated with matted uluhe fern, (*Dicranopteris linearis*) (Harrison *et al.* 1983). Dense uluhe and scattered tree cover is beneficial for soil stabilization and protection of burrows. `ohi`a (*Metrosideros polymorpha.*) roots serve to shore up burrow entrances and may act as "take-off" platforms for the birds (Leah DeForest, Point Reyes Bird Observatory (PRBO), Kaua`i 1993 pers. comm.). Like many seabirds, Newell's move awkwardly on land because their legs are situated toward the back of the body, an adaption for plunge diving and pelagic life (Harrison 1990). Because of this anatomical feature, an open downhill flight path is an essential topographical feature for nesting habitat in order for the Newell's to become airborne. Therefore, nesting habitat is limited to areas with embankments and/or slopes. The direction of slope with respect to wind direction might also be important (Craig Spencer, 1993, per. comm.). Due to increased predation pressure and land use changes, the nesting habitat utilized today is probably much more restricted than it was historically (Banko 1980a).

During the May through November breeding season the adult and sub-adults hunt for fish, plankton, and squid (Harrison 1990) offshore, visit their burrows and feed young after sunset. Most birds return to sea before dawn (Ainley and Podolsky 1993; Cooper and Day 1994; USFWS 1985).

Newell's shearwater's lay one egg and generally do not renest that season, even if the nest fails (Harris 1970; Harrison 1990). Newell's chicks fledge from October to November. Closely related Manx shearwaters begin breeding four to five years later at the colonies from which they fledged (Harris 1960, 1965, 1966, 1972). Newell's are also site tenacious to natal areas although birds sometimes colonize new areas. Despite natal site tenacity, several seabird species have been experimentally manipulated to nest in new areas as a conservation strategy. Seabird decoys and recorded vocalizations have resulted in the establishment of new breeding colonies (Podolsky and Kress 1992). The breeding biology of shearwaters is discussed in Harrison (1990; Harrison *et al.* 1983) and nesting successes of Newell's shearwater on Kaua`i is examined in greater detail by Ainley and Podolsky (1993).

Hawaiian Dark-rumped petrel or `Ua`u (*Pterodroma phaeopygia sandwichensis*):

The endangered Hawaiian Dark-rumped petrel or `Ua`u (hereafter Dark-rumped petrel) is a large seabird averaging 40 cm in length with a 90 cm wingspan. The upperparts are dark gray, the forehead and underside white, and the underwing white with black margins. The legs and upper portions of the feet are flesh-colored, but the webs are black tipped. The bill is short and stout, gray-black, and has a sharp curved tip (Pratt *et al.* 1987; USFWS 1983). Another endangered subspecies of the Dark-rumped petrel breeds only in the Galapagos Islands (Harrison 1990). The Hawaiian Dark-rumped petrel breeds only in the Hawaiian Islands, remaining out to sea during the non-breeding season.

Historically Newell's shearwater and Dark-rumped petrels may have shared nesting sites, but Dark-rumped petrels are presumed restricted to barren high altitude slopes above 2,200 meters (7,200 feet) (USFWS 1983). The largest remaining population nests in Haleakala National Park on Maui (Harrison *et al.* 1984). Small populations are known to nest or have nested on the other main Hawaiian islands. On Kaua`i, two colonies exist in the mountainous central and northwestern regions (Cooper and Day 1994). On the island of Hawai`i, small colonies existed on Mauna Kea until recently (Richardson and Woodside 1954). Scattered populations still breed on the southwest rift of Mauna Loa. There is confirmed nesting in Hawai`i Volcanoes National Park on the upper slopes of Mauna Loa (Paul Banko, NBS and Larry Katahira, NPS, pers. comm. 1994). The Dark-rumped petrel was listed as an endangered species in March of 1967 (USFWS 1983).

The only recent record of Dark-rumped petrels in the Puna District is from Banko (1980b) who heard a few calls in September of 1972 at Maka`opuhi Crater. He does not feel this presents enough evidence to support the possibility of a nesting colony at that site. However, the airspace over the Puna area may constitute a flyway, or regular flight path, to the confirmed colonies at higher elevations.

The breeding biology of the Hawaiian Dark-rumped petrel is described in Harrison (1990) and by Simons (1985).

Other seabirds and shorebirds

The Band-rumped storm petrel or `Ake`'ake (*Oceanodroma castro*) has been documented on the North East Rift of Mauna Loa, and is suspected to breed there (Paul Banko, NBS, Larry Katahira, pers. comm. 1994). The Fish and Wildlife Service has been petitioned to add this species to the federal Endangered Species List. It is currently listed as endangered by the State of Hawai`i (Pratt *et al.* 1987). The Puna district is also a potential flyway for this species.

The White-tailed tropicbird or Koa`e kea (*Phaethon lepturus*) is a non-endangered seabird species which occurs on all of the main Hawaiian Islands. White-tailed tropicbirds are regularly found flying over dense rain forest, and may nest in bare volcanic craters (Pratt *et al.* 1987). Tropic birds may occur in the project area.

Hawaiian Noddy or Noio (*Anous minutus melanogenys*) were seen in flocks of two to twenty birds along the Puna Coast. This species breeds in caves and cliffs in the main Hawaiian Islands (Conant 1980).

The Pacific golden plover or Kolea (*Pluvialis dominica*) is commonly seen during the non-breeding months (September through March) in the Kalapana Extension of Hawai`i Volcanoes National Park. Conant (1980) notes that this "shorebird" species prefers rockland, scrub, and grass communities and occurs in densities of one to five birds/40 ha. Kolea have been sighted on the rim of Napau Crater (Conant 1980) and in scattered locations throughout the Puna District.

Two other non-nesting seabirds that occur in the Puna between September and March are the Wandering tattler or `Ulili (*Heteroscelus incanus*), (USFWS 1993) , and the Ruddy turnstone or Akekeke (*Arenaria interpres*), (Conant 1980).

Table 1 lists additional seabirds and other federally protected migratory birds that may occur in the East Rift Zone.

OBJECTIVES

Data confirming the presence of seabirds within the Geothermal Project area was needed to assess the potential impacts of geothermal development on seabird populations of the Island of Hawai`i. Seabirds have been suspected to use the airspace above the subzones (Figure 1), but no baseline information existed on the current distribution of the seabird species, the location of seabird flyways, or the existence of nesting colonies.

Project objectives were to determine:

1) the presence or absence and distribution of Newell's shearwater and other seabirds within the project area;

2) approximate population size or number of birds using the land and airspace within the project area;

3) location of flyways and/or breeding sites;

4) breeding status and nesting success of the populations, if breeding sites were detected;

5) potential negative impacts or limiting factors of geothermal development on species detected within the vicinity of subzones;

6) habitat characteristics of the identified colonies;

7) colony attendance patterns; and

8) location of Newell's nesting burrows and microhabitat characterization of nest sites.

Due to land access limitations, timing constraints on the project, and seasonality of the Newell's shearwater, Objectives 2 and 8 were not completed . These objectives should be carried out for a final EIS.

MATERIALS AND METHODS

Records of seabird occurrences were obtained from a number of sources: historical literature, the Nature Conservancy's Hawai'i Natural Heritage Program (TNC 1993) rare taxa databases, and USFWS National Wildlife Research Center necropsy reports. We also questioned Paneawa Zoo employees (wildlife rehabilitation staff), a local veterinarian (M. Lapesh 1993 pers. comm.), and biologists from Hawai'i Department of Land and Natural Resources (DLNR), National Park Service (NPS) and USFWS National Wildlife Refuge for seabird records. Posters and a newspaper article (*The Hilo Tribune Herald*, 1993) about the Newell's shearwater (Figure 2) encouraged local residents to report sightings and observations. Community meetings were held at Puna and Pahoa Community Centers. Biologists showed slides and played tape recordings of vocalizations of threatened and endangered bird species known to have occurred in the Puna District. Information collected from these various resources was used to select study sites with the highest probability for detecting Newell's shearwater and other seabirds.

Survey period

Seabird surveys began late in the breeding season on July 28, 1993. Selected sites were monitored through October 21, 1993. Observers began surveys at sunset until approximately 2130 and then again before sunrise (0400) when adult seabirds are detectable flying to and from the ocean. Periodic all night surveys were also conducted.

Survey techniques

Seabird sampling was conducted as an intensive point count survey at potential colony sites, flyways, and bright light sources. One trained observer per study site identified species and numbers of birds, primarily by vocalizations. Each call was counted as a separated detection. A nighttime helicopter flight over the Puna district was conducted to locate bright light sources that might attract seabirds. Night vision goggles (model AN/PVS-5A) were used to help detect seabirds entering colony areas. Recording equipment was used periodically to document vocalizations and seabird activity at colonies. Compass bearings were taken on the direction of each seabird colonies. Compass bearings were taken on the direction of each seabird detection, and distances were estimated to each bird. Other species in the study area were also identified. At nest sites, efforts were made to minimize disturbance to nesting birds by not cutting trails, by restricting the use of bright lights, and keeping noise levels low.

Data collected

The data recorded for each survey included: survey start and end time, site description, slope, elevation, location, vegetation characteristics, number and time of detections, weather, moon phase, sunset, sunrise, direction and distance estimates to detection, other species observed and call types detected.

Study sites

Survey sites (Figure 3 and Table 2) were limited by land access to private property and by the timing of the Newell's breeding season. Cinder cones, craters, historical sightings or seabird road kill areas were surveyed first. During the Newell's fledging period (mid October) areas identified as bright light sources from the air at 8:00 P.M. on September 9, 1993 (Figure 4) were also surveyed for seabird activity or fledgling "fallout".

RESULTS

Seabird surveys conducted in the vicinity of the proposed Geothermal Project area confirmed the presence of the Newell's shearwater in the project subzones and surrounding areas. We also observed migrant waterfowl (Teal species), and migrant shorebirds (Wandering tattlers, and Pacific golden plover) as incidental sightings during Hawaiian hawk, bat, and forest bird surveys (Appendix 1).

Number of detections

Two hundred sixty Newell's shearwater detections were made during 275 survey hours. Mean detection rates were 1.26 birds/hour at Pu`ulena Crater, 1.05 birds/hour at Heiheiahulu and 0.04 birds/hour at Pu`u Kaliu (Table 3). Areas where seabirds were initially detected were monitored more frequently than areas where seabirds were not heard. Survey effort was variable between survey sites (Table 4).

One hundred sixty Newell's detections were identified at Pu`ulena and 99 detections at Heiheiahulu. Only one distant Newell's was detected near Pu`u Kaliu. This area was first surveyed August 31, late in the breeding season. In June 1992, one observer estimated greater than 50 birds in this area (L. Katahira, pers. comm. 1993). A summary of all detections is given in Table 4. Survey sites with no detections were also surveyed later in the breeding season (Table 2).

Species detections

Seabirds were identified at night on the basis of vocalizations. Although night vision equipment was used on many of the seabird surveys, only 4% of the birds were detected visually (Appendix 3). The Newell's shearwater was the only seabird detected during our surveys. Other nocturnal species recorded during the seabird survey were Barn owls (*Tyto alba*), (Table 5) and Hawaiian Hoary bats (\`Ope\`ape\`a, *Lasiurus cinereus semotus*) (refer to incidental sightings in the Bat Report).

Location of detections

Newell's shearwaters were found at three out of 19 areas surveyed. Regular and repeated seabird activity was identified at two survey sites believed to be active nesting colonies (hereafter referred to as colony sites). One location was Pu\`ulena Crater at 183 m (600 ft) elevation in the lower geothermal subzone. Another area was near Heiheiahulu (Lower Heiheiahulu) at 330 m (1000 ft) in the upper subzone. Other findings indicate potential flyways below Kaliu Crater and above Kikala near the water tank on the Pahoa-Kalapana Highway (L. Katahira, pers. comm. 1993). Two road-killed birds were collected on the highway near Leilani Estates (Table 6). An additional Newell's carcass was found in Hilo, outside the project area (Carter Atkinson, USFWS, pers. comm. 1993). Figure 5 shows the distribution of Newell's shearwater detections in the Puna District. Katahira's sighting was in June of 1992. All other detections were from the 1993 breeding season.

Timing of detections

Newell's shearwaters were detected from July 23 until September 20, with surveys conducted at colony sites until October 18. Newell's were heard from July 23 to September 10 at Pu\`ulena Crater and at Lower Heiheiahulu from August 19 until September 20. Brightly lit areas that could attract seabird fledglings were surveyed until October 21; however, no birds were observed. The peak of the Newell's shearwater fledging on Kaua\`i was October 15 for 1993 (PRBO and ABR pers. comm. 1993); however, no seabird detections were recorded during this period in Puna. The detection rate (birds per hr) dropped steadily as the breeding season progressed, from 3.4 birds/hr in July to 0 birds/hr in October (Figure 6).

Distinct daily peaks in activity were observed at colonies. Most Newell's were detected between 50 and 90 minutes after sunset (Figure 7). Morning detections peaked 247 minutes before sunrise (Figure 8). There were fewer birds detected "leaving" (morning detections) the colonies than "entering" (evening vocalizations). Mean detection rates in the morning hours were 0.34 birds/hr and 1.15 birds per/hr in the evening.

Habitat characteristics of survey sites

The dominant vegetation type and a site description for all areas surveyed for seabirds is given in Table 2 and Appendix 2. For a detailed account of vegetation types that occur in the project areas, refer to the botanical surveys report. Open tree cover (<60%) with a dense matted fern (uluhe) understory was typical of both colony sites.

The Pu`ulena colony site is a large pit crater approximately 100 meters deep with walls sloping to 78 degrees. `Ohi`a/uluhe and mixed lowland forest of hala (*Pandanus tectorius*) and kukui (*Aleurites moluccana*) occur in and around the crater. Vegetation on the walls of the crater is predominantly uluhe and an open canopy consisting of hala and `ohi`a trees. The crater walls have some sheer areas which are not vegetated. The forest on the southeast edge of the crater consists of bamboo (*Phyllostachys nigra*), mango (*Mangifera indica*), and strawberry guava (*Psidium cattleianum*).

The area surrounding Heiheiahulu is also characterized by open `ohi`a trees with dense uluhe understory. There are two pit craters and two cinder cones (pu'us) in the areas surveyed. A cow pasture is adjacent to the `ohi`a and uluhe forest. Birds seemed to be landing in the uluhe patches below the northwestern slope of Heiheiahulu. The slope was estimated at 18 degrees. Restricted access to this area prevented a more complete evaluation.

DISCUSSION

The natural ecosystems of the Hawaiian Islands have been drastically disturbed by effects of human activities such as land clearing, cattle grazing, alien species introductions, and urbanization. Today, Hawai`i is dominated by introduced vegetation with native vegetation dominating less than 40% of Hawai`i's total area (Jacobi 1985). The devastating effect of these disturbances on bird species native only to the Hawaiian Islands is discussed in the forest bird section of these reports. Presently 75% of known Hawaiian birds are extinct or threatened with extinction and listed on the Federal Endangered Species List (USFWS 1985).

Island seabird populations have been declining worldwide. Introduced species and landscape alteration further degrade the native ecosystems.

Detrimental factors affecting Hawaiian seabirds

There are a number of factors contributing to the decline of Hawai`i's seabird populations: predation pressure, particularly in areas near forest clearings and urban areas, limited areas suitable for nesting, and modified landscapes with structures and lighting unfamiliar to seabirds (Ainley 1993). Historically, burrow-nesting seabirds, eggs, and young were taken by the Hawaiians for food (Bryan 1908; Munro 1941; USFWS 1983), which may have been a major factor in reducing the populations.

Today, introduced feral and domestic animals pose the biggest threat to ground nesting seabirds. Cats (*Felis catus*), dogs (*Canis faimiliaris*), and rodents (*Rattus norvegicus*, *R. rattus*, and *R. exulans*), prey on nesting birds, eggs, and chicks (Byrd 1979; Byrd and Moriarty 1981; Conant 1980; USFWS 1983; Simons 1984, 1985; Richardson and Woodside 1954). Introduced mongooses (*Herpestus aropunctatus*) are believed to be a primary cause of the decline in Hawai`i (USFWS 1983). Newell's breeding success appears to be highest on Kaua`i, where mongooses have not become established (Ainley and Podolsky 1993; Harrison 1990). Introduced barn owls (*Tyto alba*) prey on many native birds (Snetsinger 1994), and were observed hunting in colony sites and predating nestling seabirds. Feral pigs (*Sus scrofa*) dig up and eat Newell's shearwater adults and their eggs in addition to degrading habitat. Goats (*Capra hircus*) are also known to trample nesting colonies (USFWS 1983; Sincock and Swedberg 1969).

The degradation or loss of habitat caused by invasion of exotic vegetation, development, erosion from deforestation, cinder mining, and fires has rendered many historical colony sites unsuitable for nesting (USFWS 1993). Habitat degradation also exposes seabirds to a higher level of predation. Cats and mongooses hunt along forest edges and trails taking advantage of fragmented habitat (Ehrlich *et al.* 1992). Other threats to seabirds include degradation of pelagic habitat by pollutants, depletion of food resources, and diseases such as avian malaria, pox and puffinosis (USFWS 1983).

Urbanization significantly threatens the survival of the Newell's shearwater and the Dark-rumped petrel. Hawaiian seabird mortality due to collisions with utility wires is well documented (Cooper and Day 1994; Hailman 1979; Reed et al. 1985; Reed and Sincock 1982). Bright lights are known to cause fledglings and some adult birds to become disoriented and "fallout" of the sky while flying to or from the ocean and nest sites. Newell's attraction to lights is not fully understood, but may be a response related to the bird's navigational orientation. Sunrise and the moon are important navigational cues used by nocturnal migrants. Man-made bright lights may interfere with these navigational cues (Hailman 1978). Cooper and Day (1994) found that most fall out and collisions occur in the morning hours when adult and juvenile birds are heading to sea.

On Kaua`i, 22,000 "fallout" shearwaters and petrels have been rescued and released in 14 years by the Save Our shearwater Program (SOS) (Cooper and Day 1994). Approximately 1,500 fledging shearwaters are recovered on Kaua`i annually (Ehrlich *et al.* 1992; Tefler 1979, 1992; Tefler *et al.* 1987). Many birds die from injuries received in the fall. Temporarily stunned birds may get hit by automobiles or killed by feral or domestic animals. In a roadside search conducted by Point Reyes Bird

Observatory (Ainley and Podolsky 1993) on Kaua`i, 36% of the downed birds found were dead.

Number of detections

Our survey technique can only be used to determine the presence of particular species and as an indicator of seabird activity. This technique cannot predict the actual number of birds in the colony or estimate population size. Surveillance radar techniques (Cooper *et al.* 1991) may detect other seabird species utilizing the airspaces above the geothermal subzones. We plan to conduct this phase of the study in June 1994. A study comparing the vocal activity of Newell's with number of flying targets detected using radar will be conducted in June of 1994.

Species detected

Newell's shearwaters were the only seabird detected during this survey. Newell's were more readily detected because of our close proximity to breeding colonies; and increased calling is usually associated with seabird breeding areas (Ainley 1993). We were not able to establish if other seabird species nesting on Mauna Loa used Puna as a flyway based on vocalizations. Future surveys should begin in May for optimal Newell's detection. Adult birds and new breeders visit the colony less frequently, and the rate of vocalizations decline as the nesting season progresses, thus making detections less likely. Nest failure may also contribute to a decrease in seabird "traffic".

Survey areas and location of detections

Because access was restricted we were unable to survey potential seabird nesting areas in the Upper Geothermal Subzone. Although two colony sites were located during our surveys, it is probable that seabirds are attempting to nest in other suitable habitat in all three subzones. Seabird activity and vocalizations are thought to decrease after pair bonding is established. Trips to the burrow for feeding decrease as chicks grow older. Because of the late timing of our surveys during 1993, it is possible that areas in which we did not detect seabird activity serve as flyway corridors earlier during the breeding season.

The two downed birds from Puna and the one from Hilo are important records confirming seabird mortality on the island of Hawai`i due to collision with utility structures and/or cars. Adult mortality during spring "fallout" is recognized as more detrimental to Newell's shearwater populations than fledgling mortality (Ainley 1993). Greater than 90% of successful fledglings (chicks that live long enough to leave the nest) do not live to reproduce five-six years later. If adults die, pair bonds are broken and if an egg has been laid or a chick has hatched, the remaining parent is unable to incubate the egg or feed the chick alone.

Detectability of seabirds

Many factors affect the detectability of seabirds surveyed at night. It has been suggested, (Lockley 1942 *in* Lockie 1952) that Manx shearwaters vocalize at colonies to effectively home-in to their nesting burrows at night. The frequency of vocalizations is thought to vary with weather, moon phase, breeding phenology, number of birds, and nesting success. We were not able to evaluate these factors with our limited data set. Other studies have shown a greater incidence of seabird collisions and fallout during periods of bad weather or during the new moon (Tefler *et al.* 1987; Warham 1990).

Possible causes for no fledgling detections or no autumn "fall out"

On Kaua`i, researchers have shown a decline in the rate of birds detected after June, except for an activity peak on October 15. The increase in the number of seabird detections in mid-October 1993 was attributed to fledglings leaving the colonies on their way to the sea (Cooper and Day 1994). Fallout rates on Kaua`i are highest during this period.

The absence of fallout in Puna when fledgling shearwaters leave for the sea is possibly due to:

1) few or no successful nests. This is probable, since large colonies monitored on Kaua`i (64 burrows monitored) showed very poor nest success with only 4 fledglings produced (Ainley and Podolsky 1993). Nest failure is even more likely on Hawai`i, which, unlike Kaua`i, has large mongoose populations known to prey on eggs and young;

2) coastal development, bright light sources, and utility structures having not reached such a threshold as to cause significant mortality in Puna;

3) fallout birds are predated, not reported, or are difficult to detect;

4) fledging young birds are difficult to detect by vocalization techniques.

Timing of detections

Most Newell's arrived at colony sites within an hour of complete darkness (Table 4). Cooper and Day (1994) had similar findings using radar sampling techniques. Our survey results showed morning detections were earlier than expected (Table 5). Cooper and Day (1994) showed a peak in morning activity with detections highest 30 minutes before sunrise. It is possible that many of the early morning vocalizations were actually late arrivals to the colony. Radar surveys can be used to determine direction of flight and provide information about the number of birds entering and leaving the vicinity of colonies.

More birds were heard during the evening hours of our surveys. Possible explanations for this observation include Lockie's (1952) description of homing behavior by seabirds to locate their burrows. If vocalization behavior is indicative of homing into burrows, a return flight to sea would not require the "homing" vocal behavior.

Additional Newell's nesting habitat in the project areas

The vegetation structure and composition of colony sites in Puna is similar to that favored by Newell's nesting on Kaua`i; however, the topography is different. On Kaua`i, Newell's nest on razorback ridges and cliffs (Tefler *et al.* 1987), whereas in the Puna District pu'us and craters appear to be the important habitat. Scattered `ohi`a cover with a dense uluhe understory was typical of colony sites on both islands.

Based on the vegetation and topography, many areas with restricted access are potentially good nesting habitat for the Newell's (i.e. I`ilewa Crater, Maka`opuhi Crater, Kahuwai Crater, and numerous unnamed craters and pu`us within the upper geothermal subzone). These areas should be surveyed in the spring during the 1994 breeding season.

POTENTIAL IMPACTS OF THE PROPOSED GEOTHERMAL DEVELOPMENT

By addressing the major factors that potentially disrupt seabird populations, steps to minimize the effects of proposed geothermal development can be implemented. Conservation measures necessary to protect seabirds have been incorporated into our mitigation recommendations. Potential impacts on seabirds could result from the following disturbances:

1) <u>Land clearing and road building for geothermal project operations</u>

Land clearing is potentially detrimental to the Newell's shearwater because of the scarcity of native dominated lowland rain forest. Lowland native forest with scattered trees and matted fern between 150 - 700 meters elevation is nesting habitat for Newell's (USFWS 1983). Less than ten percent of the original lowland `ohi`a rain forest remains today (Jacobi 1985). A relatively large area of this forest type exists within the geothermal subzones.

The proposed geothermal development will minimally use 422 acres out of 25,461 acres of project land (True 1982). An access road of 7.5 miles (30 ft wide) and an unspecified number of secondary roads are proposed. Clearing for transmission lines, conductor string sites (100-200 ft. clearings every 3 miles), and powerlines with 25 - 40 ft. corridors fragment potential habitat and create favorable conditions for aggressive non-native plant species (refer to the botanical section of these reports). Negative impacts to Newell's shearwater include weed invasions into formerly suitable nesting habitat.

Roads and clearings also facilitate predator access and potentially increase the threats of predation on nesting birds. Rat, cat, dog, and mongoose populations are most dense in areas associated with human activity (Ehrlich *et al.* 1992). Barn owls are also adapted to areas associated with human activity. They hunt in clearings and other open areas (Clark *et al.* 1978).

All areas with suitable terrain and vegetation should be protected for shearwater nesting. The natural vegetation around and inside all pu`us and craters should be protected. Land clearing or other disturbances such as cinder mining or drilling near these areas would be detrimental to the nesting efforts of the Newell's in Puna.

2) Utility structures and lighting

The impacts of utility wires on the Newell's shearwater and Dark-rumped petrels are well documented and currently being studied for the Electric Power Research Institute (Ainley and Podolsky 1993, Cooper and Day 1994). Findings from these studies attribute the occurrence of seabird collisions to the increase in manmade structures located in previously open airways. Researchers consider disorientation by bright light sources and collision with utility structures to be the second most significant cause of seabird mortality in Hawai`i; the first being predation by introduced predators (Ainley and Podolsky 1993, Cooper and Day 1994). The combined impacts of fallout with predation of downed birds places birds in greater jeopardy.

The impacts of overhead transmission lines on avian species is discussed in detail by Evans *et al.* (1993) in the section of this report on endangered waterbirds near the geothermal transmission lines. Drilling equipment, power plant cooling towers, bright light sources used for night operations, and other utility structures of the geothermal plant are likely to cause seabird fallout.

3) Standing water

Standing water in the project areas could both attract and negatively impact migratory waterfowl. Silica dropout ponds, surface discharge of geothermal fluids, and standing water resulting from construction activities may act as an "attractive nuisance" possibly attracting migrant birds to these potentially harmful artificial wetlands and ponds (Karen Evans, USFWS, pers. comm.).

The accumulation of standing water due to construction activities can also provide breeding sites for mosquitoes (*Culex sp.*), which are vectors for avian malaria and pox. Mosquitoes could infect nesting seabirds near standing water at the geothermal project sites, as well as other developed areas (USFWS 1983).

4) Emissions and noise

Noise and emissions from geothermal operations may be disruptive or harmful to nesting birds. However, we are not aware of studies that have attempted to quantify these effects on seabirds.

MANAGEMENT RECOMMENDATIONS

In order to minimize the risks to seabird populations, management recommendations include the following measures.

1) Avoid areas suitable for nesting. All sloped areas with open `ohi`a forest and uluhe understory should be avoided along with a surrounding buffer zone.

2) Time construction outside the breeding season (April-November). Construction, drilling, installation of transmission lines, and road construction should occur between December and March for minimum impact on breeding birds. Surveys of construction sites, road ways, and secondary roads for seabird colonies should be conducted prior to construction.

3) Equip project lights with automatic shut off. Lights should be turned off during the hours of peak seabird activity, 1-1.5 hrs. after sunset and approximately 3.5 hrs. before sunrise during the breeding season.

4) Project lights should be shielded. Reed *et al.* (1985) demonstrated reduced light attraction in Hawaiian seabirds by reducing upward radiation.

5) Use long-wavelengths with mixed red or orange light Orange or mixed-red light are believed to be less of an attractant (Reed and Sincock 1982). Short-wavelength light found in the bright "white or bluish" light sources on Kaua`i are attributed to the most greatest fallout. White mercury-vapor, mercury-halide, "cool" fluorescent, and incandescent lights have also been known to cause seabird fall out (Hailman 1979) and are not recommended.

6) Use marker balls on transmission lines. Marker balls have been shown to reduce collisions (Cooper and Day 1994).

7) Predator control. Establish a predator control program to reduce the number of cats, rats, mongooses, and dogs found in or adjacent to seabird nesting areas.

Roads, which serve as traveling routes for these predators, should be particularly targeted for this control program near potential nesting areas.

8) Establish a program for the rehabilitation of downed birds. A downed-bird recovery and rehabilitation program, particularly with a community support component, was found to be extremely effective on Kaua`i in reducing mortality in seabirds that collided with structures (powerlines, poles, etc.) after being disoriented by lights. We recommend the establishment of a similar program in areas on the island of Hawai`i that have seabird fallout problems.

9) Establish new nesting colonies in protected areas using decoys, vocalizations, and predator control. Relocate or encourage birds to breed in areas where there is less conflict between structures, lights and birds (Podolsky and Kress 1992). However, this step may not be necessary if other management recommendations are successfully implemented.

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Table 1. Seabirds, migrant waterbirds, and migrant shorebirds found or potentially found in the geothermal subzones.

Common name	Species	Regulatory Status[a]
Northern pintail	*Anas acuta*	MB
American widgeon	*Anas americana*	MB
Northern shoveler	*Anas clypeata*	MB
Green-winged teal[b]	*Anas crecca*	MB
Eurasian widgeon	*Anas penelope*	MB
Black noddy, Noio	*Anous minutus melanogenys*	MB
Ruddy turnstone, 'Akekeke	*Arenaria interpres*	MB
Lesser scaup	*Aythya affinis*	MB
Sanderling, Hunakai	*Calidris alba*	MB
Wandering tattler[c], 'Ulili	*Heteroscelus incanus*	MB
Band-rumped storm petrel, Ake'ake	*Oceanodroma castro*	MB, HE
White-tailed tropicbird, Koa'e kea	*Phaethon lepturus*	MB
Hawaiian Dark-rumped petrel, 'Ua'u	*Pterodroma phaeopygiga sandwichensis*	MB, FE, HE
Pacific golden ploverc, Kolea	*Pluvialis dominica*	MB
Newell's shearwater[c], A'o	*Puffinus puffinus newelli*	MB,FT, HE

[a] Regulatory status of each species protected by U.S. the Migratory Bird and Endangered Species Acts. FE = Federally Endangered, FT = Federally Threatened, HE = State of Hawaii Endangered, MB = Migratory Bird

[b] These species were observed during surveys. Refer to Appendix 1 for location and date of sighting.

[c] An unidentified teal species was found at Kapoho crater in the lower subzone. Other duck species found wintering in Hawaii may also occur within the subzones.

Table 2. Site desription, elevation, and summary of results for areas surveyed for seabirds in the Puna District in 1993.

Survey location	Survey dates[a]	Elevation in me(ft)	Site description[b]	Newell's detected
Ainaloa Greenhouse	Oct. 14	170 (560)	BLS[c]; Cleared residential area with greenhouse	No
Heiheiahulu	Aug. 19- Oct. 19	442 (1450)	Open canopy ohia/uluhe forest next to pasture, surrounded by puus and craters	Y
Herbert C. Shipman Park	Oct. 13- Oct. 21	104 (340)	BLS; Mixed lowland forest surrounding manicured park area	No
Hawaii Tropical Products (Keaau)	Oct. 13- Oct. 15	61 (200)	BLS; Fallow sugar cane and fragmented mixed lowland forest	No
Isaac Hale Beach Park	Sept. 16	3 (10)	Coastal mixed lowland forest scrub, bordering ag land	No
Kalapana	Sept. 23- Oct. 14	3 (10)	Lava flow with pioneer vegetation	No
Kahuwai Crater	Oct. 19	213 (700)	Mixed lowland forest with ohia /uluhe	No
Kaueleau	Oct. 14	232 (760)	Coastal mixed lowland forest and ohia woodland	No[d]
Kumakahi Lighthouse	Sept. 16- Oct. 14	12 (40)	BLS; coastal lava flow with early pioneer vegetation	No
Orchid Land Wiki Wiki	Oct. 14- Oct. 21	165 (540)	BLS; Residential area with fragmented vegetation	No
Pahoa Town	Oct. 14	207 (680)	BLS; Developed area with fragmented mixed lowland forest	No
Pawai Crater	Aug. 25- Oct. 19	152 (500)	Pit crater, mixed lowland forest with substantial ohia/uluhe	No
Puna Geothermal Venture	Oct. 13- Oct. 21	183 (600)	BLS; Fragmented mixed lowland forest with puu and industrial development surrounded by ag land	No
Puna Biomass Power Company (Keaau)	Oct. 13- Oct. 21	61 (200)	BLS; Fallow sugar cane fields with fragmented mixed lowland forest	No

Table 2. (Continued).

Survey location	Survey dates	Elevation in me(ft)	Site description	Shearwaters detected
Puu Kaliu	Aug. 25- Oct. 18	305 (1000)	Closed canopy ohia with predominantly exotic understory and heavy excavation on south side of puu	Yes
Pu`ulena Crater	July 23- Oct. 19	183 (600)	Large crater 100 me deep, surrounded by mixed lowland forest and ohia/uluhe	Yes
Route 130	Oct. 14- Oct. 15	82 (270)	BLS = Street Lights; Continuous route; n/a	No
Route 132	Oct. 14	67 (220)	BLS = Street lights; Continuous route; n/a	No
U. S. Cellular Tower (near Pu`u Honuaula)	Sept. 1- Sept. 16	213 (700)	Mixed lowland forest in small crater surrounded by ag land	No

[a] First and last dates for which shearwaters were surveyed.

[b] Components of the site descriptions are defined in Appendix1

[c] BLS in site description = bright light sources.

[d] Residents reported hearing shearwaters fly near their house June through August, 1993.

Table 3. Summary of Newell's shearwater detections in the Puna District in 1993.

Location	Survey dates[a]	Number of detections[b]	Number of detections per hour
Lower Heiheiahulu	Aug. 19	32	11.64
	Aug. 23	20	6.15
	Aug. 26	2	0.67
	Aug. 31	15	4.29
	Sept. 1	3	1.53
	Sept. 2	1	0.29
	Sept. 8	2	0.34
	Sept. 9	2	1.00
	Sept. 10	3	0.95
	Sept. 16	4	1.18
	Sept. 20	6	1.69
		total=99	mean: 1.05
Pu`ulena Crater	July 23	13	14.18
	July 28	7	3.23
	July 29	2	1.00
	Aug. 9	5	3.16
	Aug. 10	7	1.00
	Aug. 25	2	0.35
	Aug. 26	19	71.25
	Sept. 9	89	23.52
	Sept. 10	16	14.77
		Total = 160	Mean = 1.26
Pu`u Kaliu	Sept. 1	1	0.67
		Total = 1	Mean = 0.04

[a] Dates are only given for survey dates in which seabirds were detected. A complete listing of survey dates and times is given in Table 4.

[b] Each vocalization was recorded as an individual detection.

Table 4. Seabird survey effort for all surveys conducted for the Newell's Shearwater between July and October 1993. Underlined times indicate overnight surveys.

Area	Date	Time start	Time end
Ainaloa Greenhouse	14 October	17:30	18:15
Near Heiheiahulu	19 August	19:15	22:00
	22 August	18:15	21:30
	26 August	19:01	22:00
		19:13	20:52
	31 August	17:35	21:05
		18:15	21:31
		22:15	22:15
	1 September	04:22	08:00
		18:57	20:55
	2 september	18:18	21:48
	3 September	03:36	06:16
	8 September	18:00	23:50
	9 September	04:00	6:00
		18:22	23:30
	10 September	03:20	06:30
	16 September	17:50	21:14
	20 September	17:39	21:12
	21 September	17:45	23:44
	22 September	02:30	02:45
		04:00	06:45
	28 september	18:00	23:11
	29 September	04:04	06:30
		17:50	21:00
	6 October	17:02	21:00
	7 October	17:15	21:42
	14 October	<u>18:40</u>	<u>05:25</u>
	19 October	18:05	21:30
Herbert C. Shipman Park	13 October	20:45	20:45
	19 October	21:50	22:00
	21 October	21:08	21:20
HI Tropical Products	13 October	20:32	20:40
	14 October	20:27	20:56
	15 October	19:15	19:30
Kahuwai Crater	19 October	17:35	18:45
Kaueleau	14 October	18:05	19:40

Table 4 . Continued

Area	Date	Time start	Time end
Kumakahi Lighthouse	16 September	17:45	19:00
	22 September	18:15	19:35
	14 October	17:31	21:05
Orchidland Wiki Wiki	14 October	18:27	19:30
	15 October	20:47	21:20
	19 October	21:20	21:25
	21 October	19:59	20:07
Pahoa High School	13 October	20:45	20:45
	19 October	21:04	21:14
Pahoa Town	14 October	-----	-----
Pawai Crater	25 August	19:05	21:20
	1 September	17:48	21:30
	15 September	18:28	20:15
	28 September	17:58	21:15
	5 October	17:33	22:00
	14 October	17:40	21:15
	19 October	18:58	20:00
Puna Geothermal Venture	13 October	18:01	6:00
	14 October	18:10	1:20
	15 October	3:55	5:52
		19:00	20:05
	16 October	4:30	6:15
	19 October	20:24	20:54
	21 October	17:33	18:57
Puna Biomass Power Company	13 October	17:50	20:30
	14 October	19:51	20:21
	15 October	17:30	19:15
	19 October	21:30	21:45
	21 October	20:25	21:00
Puu Kaliu	25 August	18:25	6:00
	1 September	19:15	20:45
	2 September	18:30	23:00
	3 September	3:50	4:55
	16 September	17:26	21:38
	15 October	19:31	22:00
	16 October	4:01	6:00
	18 October	17:43	19:03

Table 4. Continued

Area	Date	Time start	Time end
Puulena Crater	23 July	19:20	20:15
	9 August	19:30	21:05
	10 August	17:00	5:00
	25 August	16:10	21:50
	26 August	1:50	2:06
		4:40	6:00
		18:30	4:15
	31 August	14:45	6:00
	1 September	18:00	21:30
	9 September	22:50	22:50
	9 September	17:33	21:20
	10 September	2:00	2:00
		4:00	6:24
		19:40	20:45
	14 September	18:09	22:30
	15 September	4:00	5:47
		17:20	21:00
	16 September	19:15	21:10
	21 September	17:27	23:00
	22 September	4:00	6:50
		17:30	23:20
	29 September	17:26	21:30
	30 September	17:49	24:00
	6 October	3:55	5:18
	14 October	17:55	6:40
	16 October	4:30	6:30
	19 October	17:30	20:12
Route 130	14 October	18:30	20:00
	15 October	5:35	6:10
Route 132	14 October	17:31	21:05
U.S. Cellular Tower	1 September	18:55	21:25
	16 September	19:02	20:50

Table 5. Summary of barn owl detections at all Newell's Shearwater survey sites.

Area	Number of detections[a]	Comments
Heiheiahulu	14	
Kaueleau	1	
Kea'au Plaza	1	Flew over shopping plaza towards highway
Kumakahi Lighthouse	2	Two owls were observed flying in the beam of light
Pawai Crater	24	Calls were heard in and around the crater; a screech followed by crashing in vegetation was once heard from inside the crater
Puna Geothermal Venture	8	Owls were observed flying over the geothermal plant and in the adjacent papaya field
Puna Biomass Power Company	2	
Puu Kaliu	12	
Pu'ulena Crater	75	Owls were heard around and inside the crater.
Route 130	3	
Route 132	4	
U.S. Cellular Tower	2	

[a] A detection refers to a single auditory or visual observation of a barn owl and does not necessarily represent exact numbers of birds at that site.

Table 6. Newell's Shearwaters found dead and reported to the U.S. Fish and Wildlife Service in 1993.

Date	Location	Age	Cause of death
1 May 1993	Route 130 mm 14	AD	unknown
1 June 1993	Route 130 mm 14.3	AD?	severe trauma[a]
28 July 1993	Lanikaula (Hilo)	AD	trauma, possibly shot[a]

[a] Cause of death was determined by necropsy (C. Atkinson, USFWS National Wildlife Research Center, per. comm.)

Appendix 1. Shorebirds and waterbirds detected during surveys in the Puna District between October 1993 and February 1994.

Species	Date	Area	Number of birds
Wandering tattler (*Heteroscelus incanus*)	7 October 1993	Kalapana	2
Golden plover (*Pluvialis dominica*)	13 October 1993	Puna Geothermal Venture	2
	21 October 1993	Puna Geothermal Venture	1
	6 January 1994	Kaohe Homestead Rd	1
	6 January 1994	Kaohe Homestead Rd	1
	10 January 1994	Route 11	1
	21 January 1994	Kapoho Crater	1
	2 February 1994	Route 11	1
	2 February 1994	9th St, Hawaiian Acres	1
	2 February 1994	Herbert C. Shipman Park	1
unknown teal (*Anas* sp.)	21 January 1994	Green Lake (Kapoho Crater)	1

Appendix 2. Vegetation associations for all seabird survey sites[a].

Area	Vegetation associations
Ainaloa Greenhouse	Wet open ohia and exotic tree canopy, matted fern and exotic shrub and grass communities
Heiheiahulu	Wet matted fern, exotic shrubs, scattered ohia
Herbert C. Shipman Park	Wet exotic forest with exotic grass and shrub layers
HI Tropical Products	Wet exotic grasses and shrubs, open exotic canopy
Isaac Hale Beach Park	Mesic coastal mixed native and exotic shrub layer, open exotic canopy
Kahuwai Crater	Wet open ohia forest with scattered exotic trees, matted fern and exotic shrub understory
Kalapana	Mesic closed exotic forest with exotic grass and shrub communities bordering new lava flow
Kaueleau	Wet mixed exotic and native shrub community with mixed ohia and exotic canopy
Lighthouse	Dry exotic grass and mixed exotic-native shrub community with very scattered exotic trees
Orchidland Wiki Wiki Mart	Wet open exotic tree canopy with some ohia, matted fern and exotic shrub understory.
Pahoa Town	Wet exotic shrub understory with open exotic trees
Pawai Crater	Wet open mixed ohia and exotic forest with matted fern understory and exotic shrubs
Puna Geothermal Venture	Wet exotic tree forest with scattered ohia and exotic shrub community
Puna Biomass Power Company	Wet exotic grass and shrub community with open canopy of exotic trees
Pu'u Kaliu	Mesic ohia forest with mixed native and exotic trees, matted fern and exotic shrub community
Pu'ulena Crater	Wet mixed exotic tree and ohia forest with exotic shrub community
U.S. Cellular Tower	Mesic open mixed exotic tree-ohia canopy with exotic shrub community

[a] Some sites, such as highways, covered too much area for a vegetation association to be applicable.

Appendix 3. Summary of visual and auditory detections of Newell's Shearwaters in the Puna District in 1993.

Survey site	Date	Time	Number of detections
VISUAL DETECTIONS:			
Puulena Crater	28 July	1925	5
		1945	1
	29 July	1940	1
Heiheiahulu	26 August	1901	2
	31 August	2215	1
	20 September	1902	1
			total: 11
TOTAL AUDITORY DETECTIONS: 249 (July 28 - September 20)			

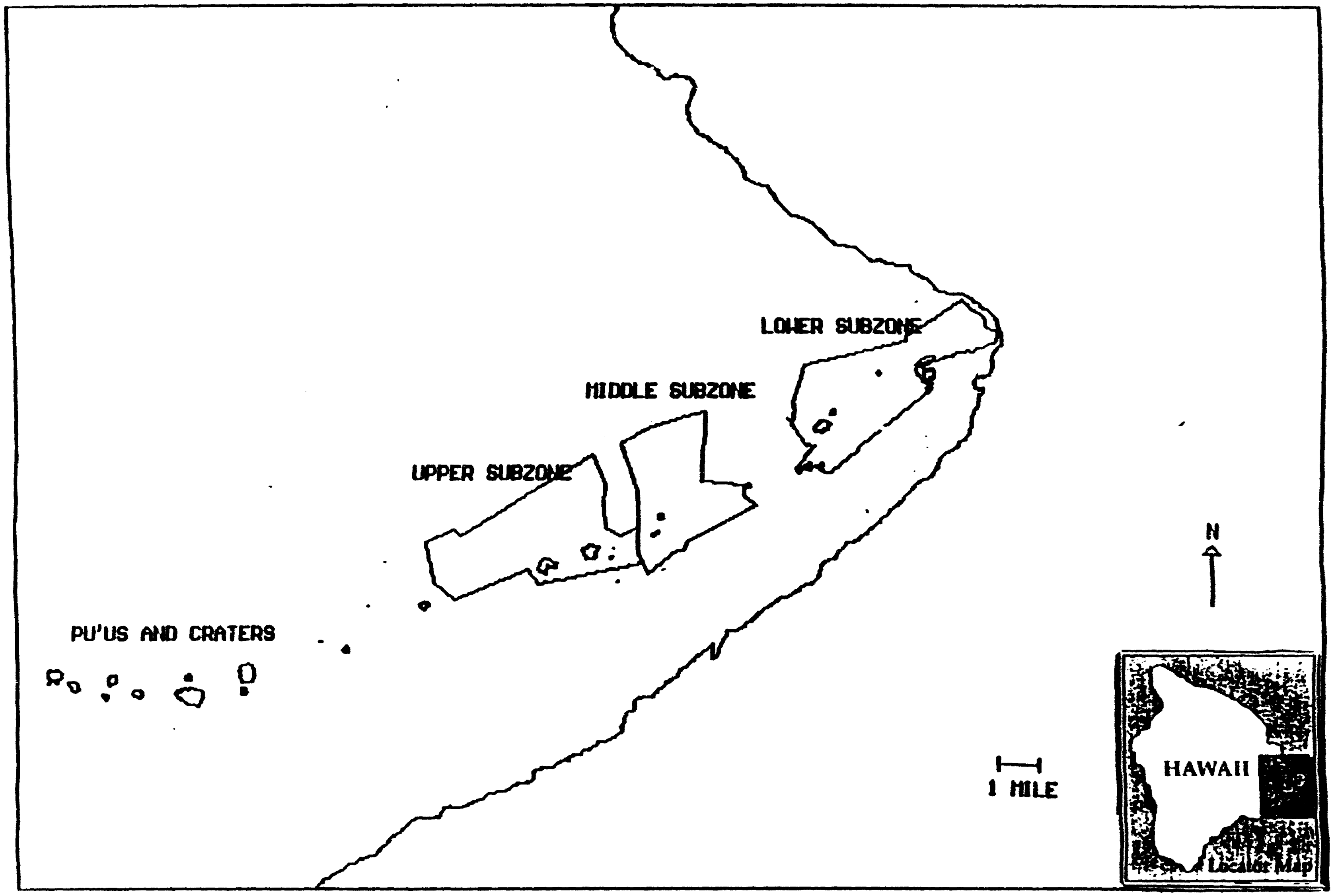

Figure 1. Geothermal subzones: proposed project areas.

Endangered seabird needs hel

Have you seen this bird? Or more likely, have you heard this bird? The mysterious nocturnal calls it makes sound like a combination of a crying baby and a braying jackass.

The 'A'o or Newell's Shearwater (Puffinus newelli) is a native Hawaiian seabird on the U.S. Endangered Species List. At one time this threatened species was believed to nest only on Kauai and Maui, but this year a small breeding population has been rediscovered in Puna on the Big Island.

'A'o nest underground in uluhe (fern) covered burrows. These seabirds move awkwardly on land and need open sloped areas, cliffs, pu'us or craters for take offs. During the nesting season the adult 'a'o hunt for food offshore, returning to feed their hungry chicks after sunset, and returning to sea before dawn. Fisherman use the 'a'o to help locate schools of ahi and aku.

The 'a'o is approximately the size of a large pigeon. Its upper parts of the body, head, neck, back, wings and tail are black and its underside is white. Their bill is thin and sharply hooked. They also possess webbed feet with short claws developed for climbing and burrowing.

The 'a'o is threatened due to several factors such as predation from introduced rats, mongooses, cats and pigs, habitat destruction, and bright artificial light sources. Newell's Shearwater have a natural attraction toward light. This poses a problem for the juvenile and inexperienced 'a'o that are just learning how to navigate. While fledging, the young birds are attracted toward artificial lights before making it to the safety of the ocean. Many birds become confused, disoriented, or may suffer from temporary night blindness. This often causes them to fly into obstructions such as trees, telephone wires and buildings. Often these birds are only stunned but fall prey to feral or domestic animals, get hit by automobiles or they simply cannot find suitable space to take off again.

On Kauai where the 'a'o population is much larger and the "fall-out" problem much more common, they devised a "Save our Shearwater" campaign. This encouraged residents to report fallen birds or to bring them to aid stations. The program has proved to be very successful with approximate 1,500 birds recovered and released annually. Some resorts on Kauai have also helped by shielding upward radiating lights and cutting down on outdoor lighting during the fledging season. The fledging season is from October to November. If you find a downed bird carefully place a small towel over its head and body to catch, then place it in a cardboard box wtih air holes. Take special care when lifting the bird, it may be injured. Please contact the U.S. Fish and Wildlife Service at 967-7396 birds are found. Uninjure can be released at the Please contact the U.S. Fi Wildife Service at 967-7 any birds are found.

ENDANGERED — The 'A'o is a native Hawaiian bird found Big Island that is on the U.S. Endangered Species List.

Figure 2. Article submitted to the local newspaper: Hilo *Herald Tribune*, October 10, 1993.

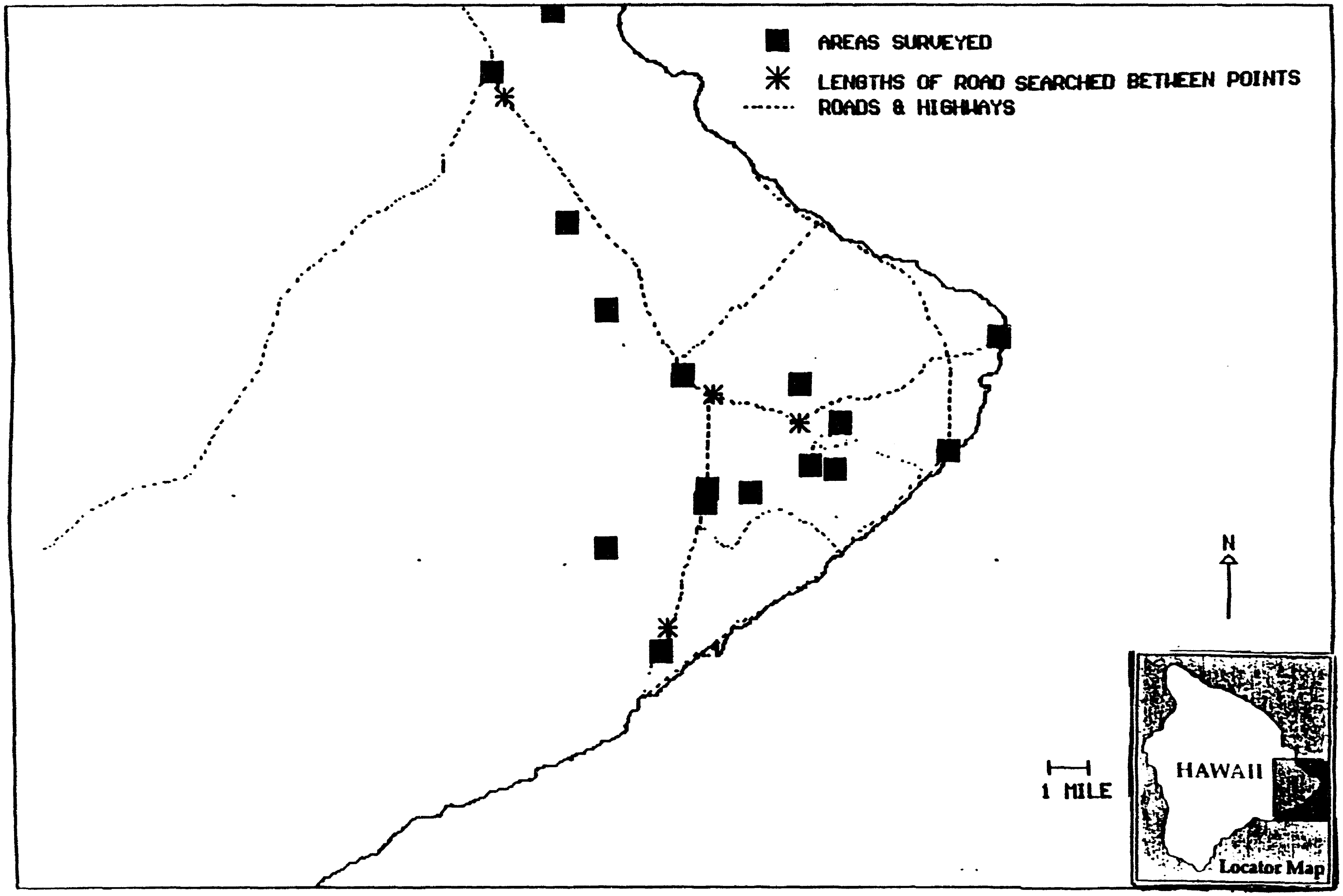

Figure 3. Locations of seabird survey areas

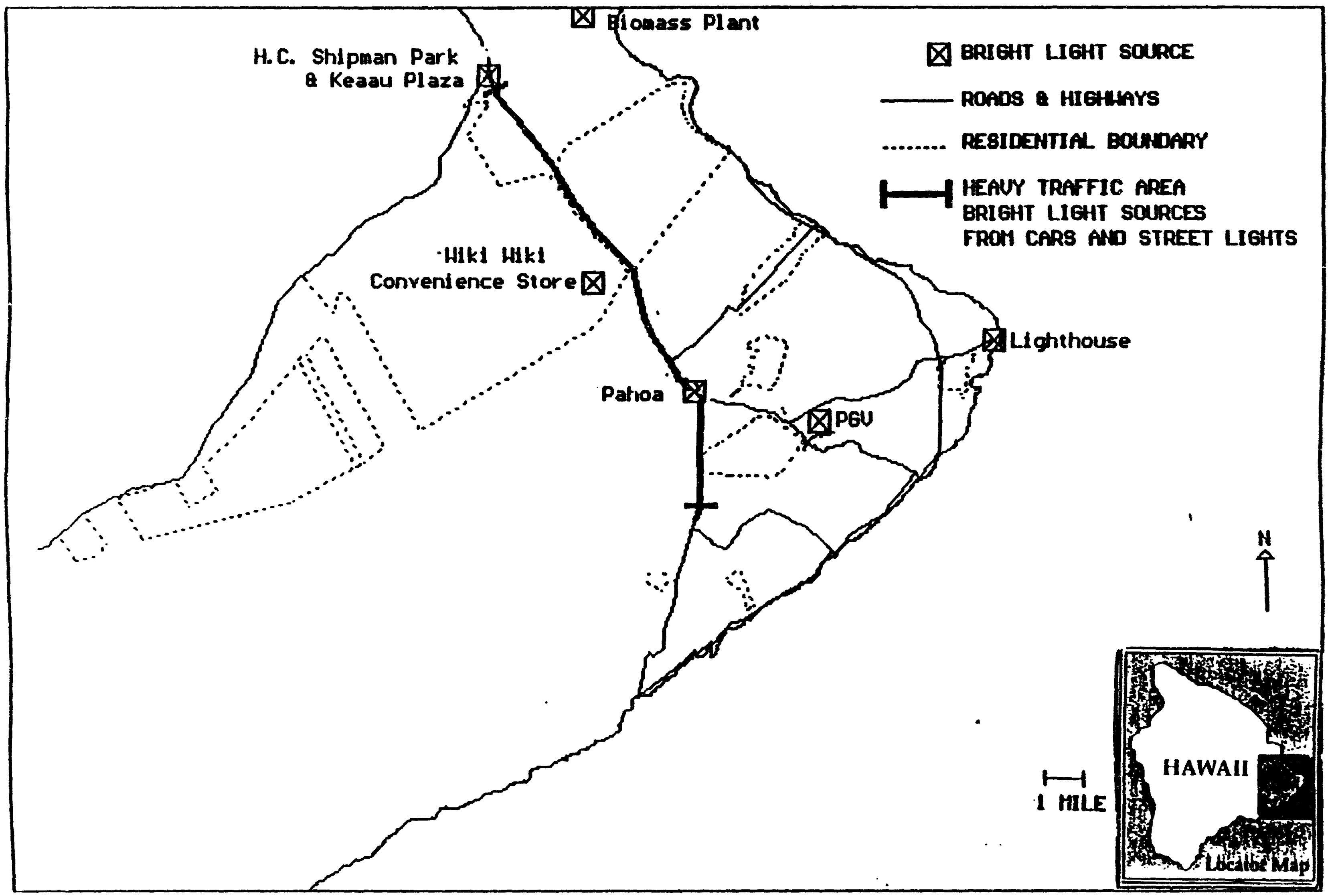

Figure 4. Bright light sources in the Puna district potentially impacting seabirds. Sources were identified on Sept. 9,1993, 8:00 P.M.

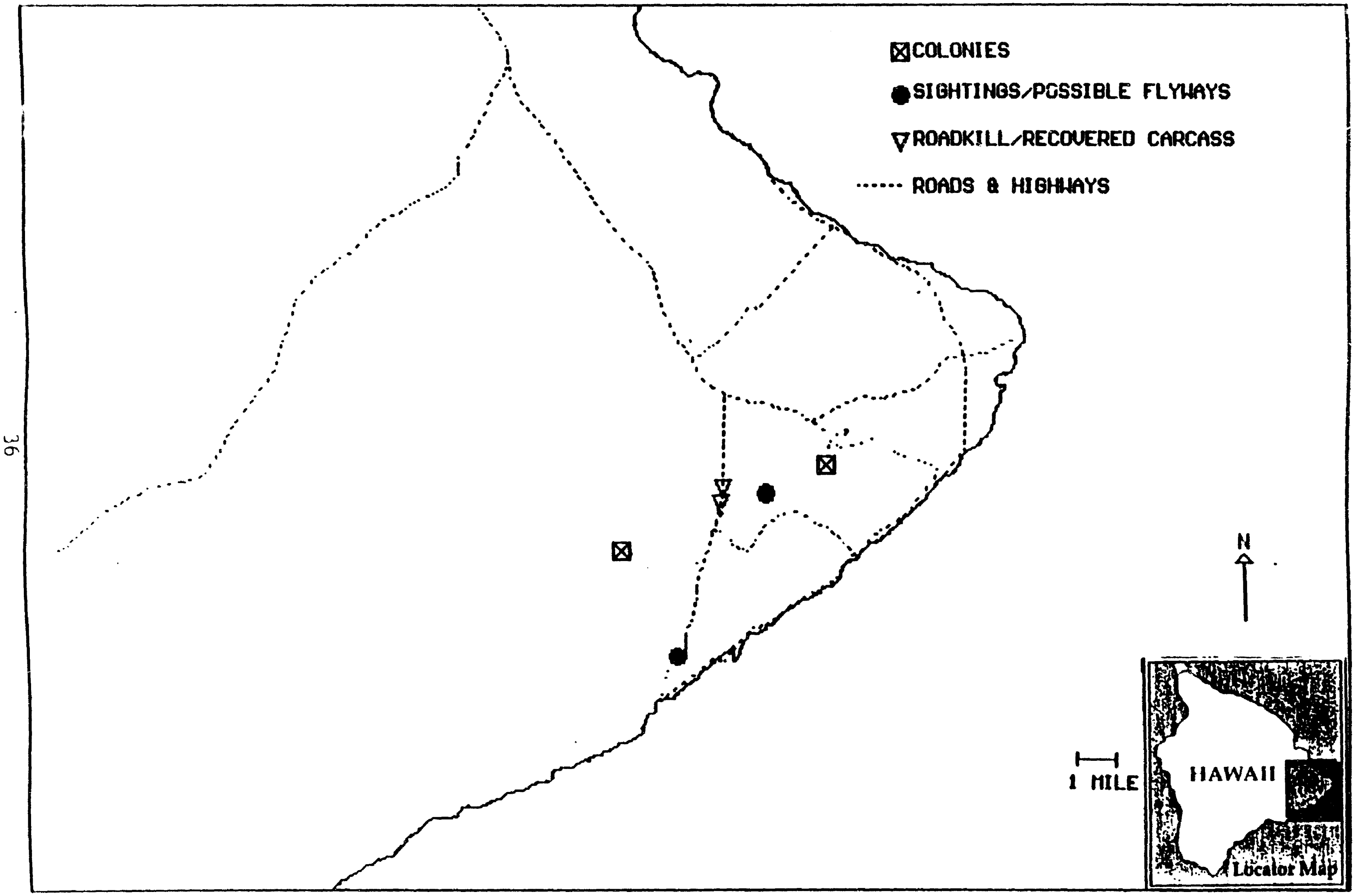

Figure 5. Location of Newell's shearwater detections in Puna, 1993.

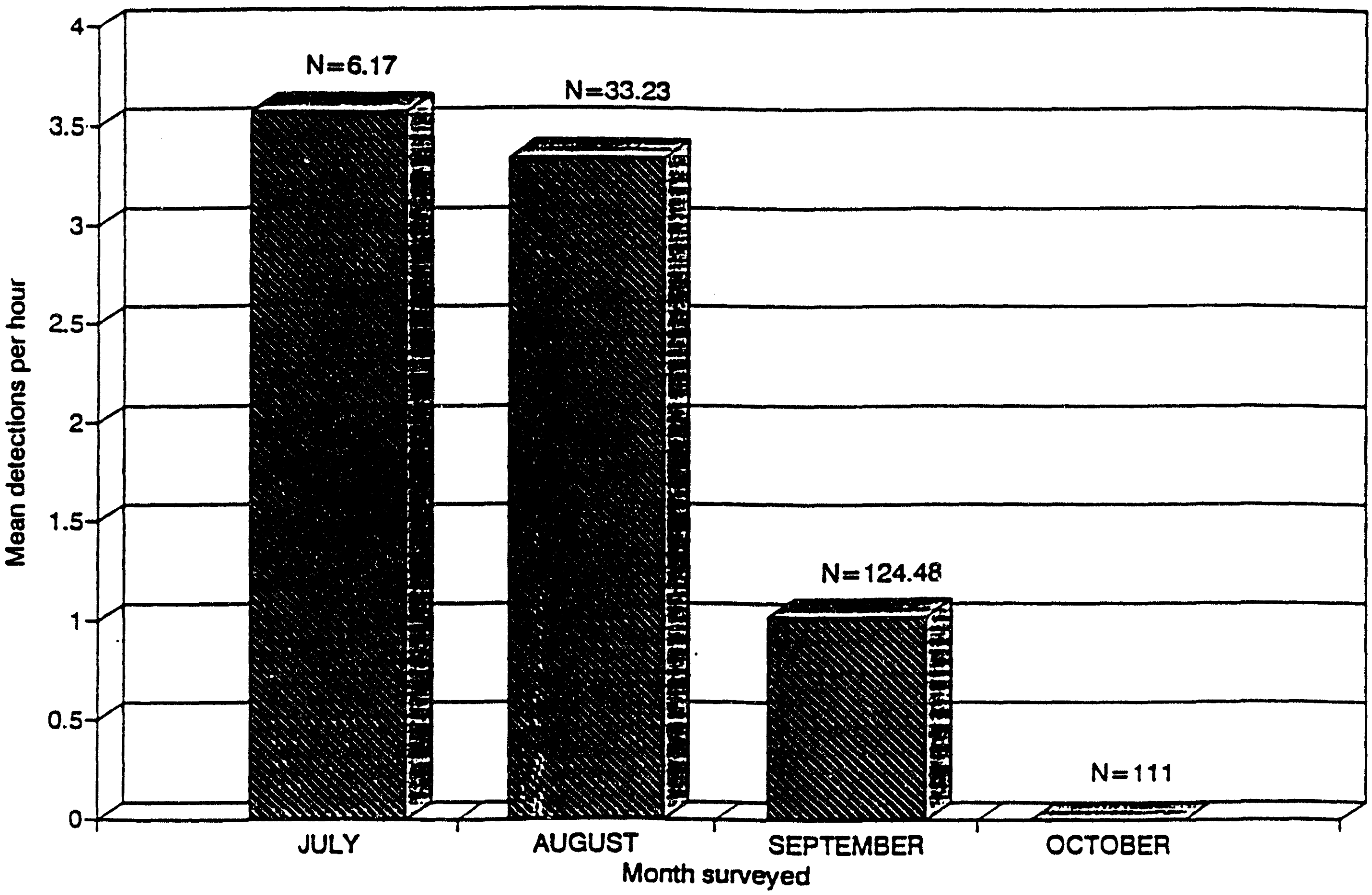

Figure 6. Mean monthly detection rates of Newell's shearwater for surveys conducted from July to October 1993. N equals the total survey hours for each month.

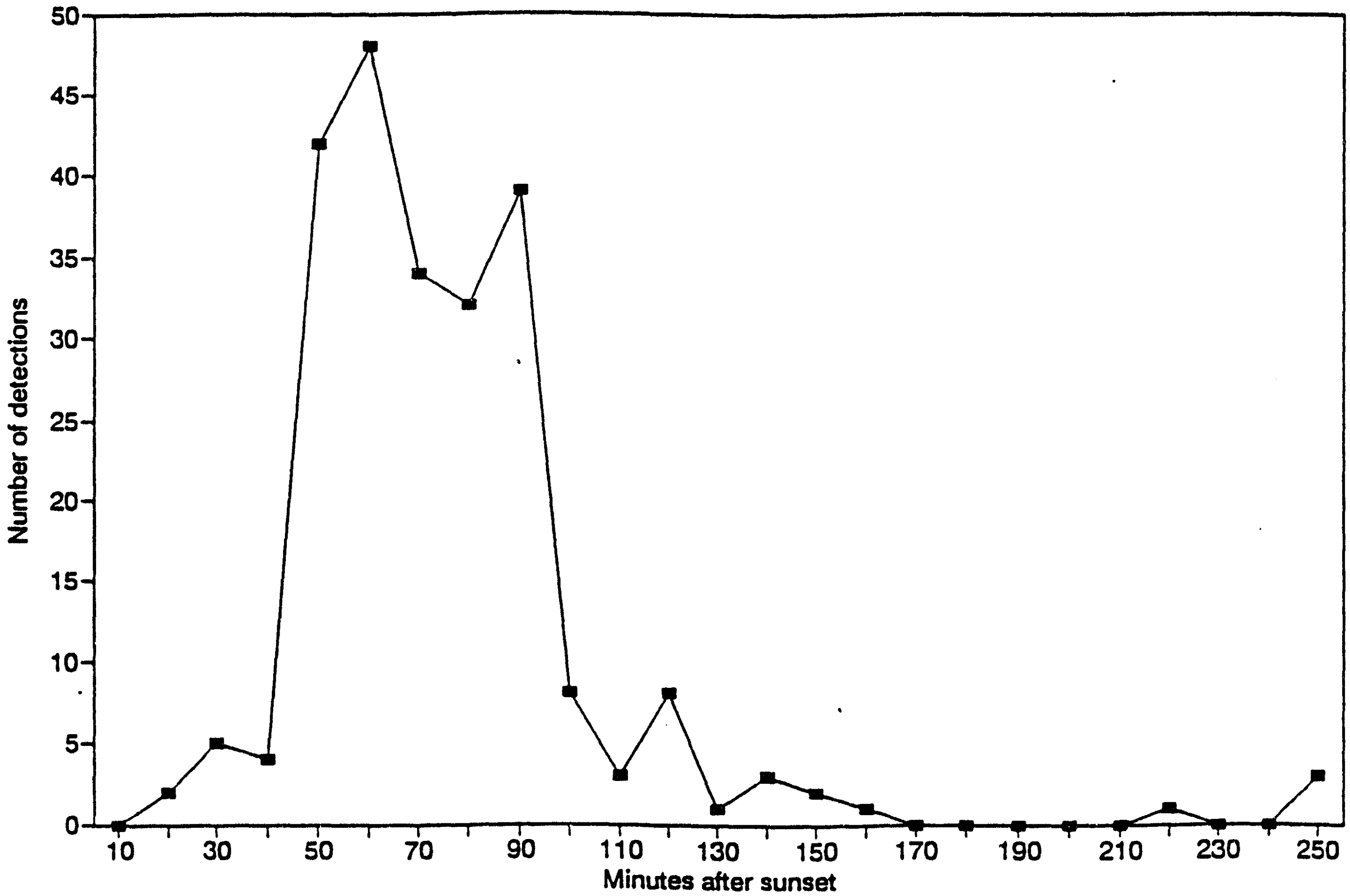

Figure 7. Evening activity pattern of Newell's shearwaters at two colony sites in Puna. Detection times are based on vocalizations heard between July and October 1993.

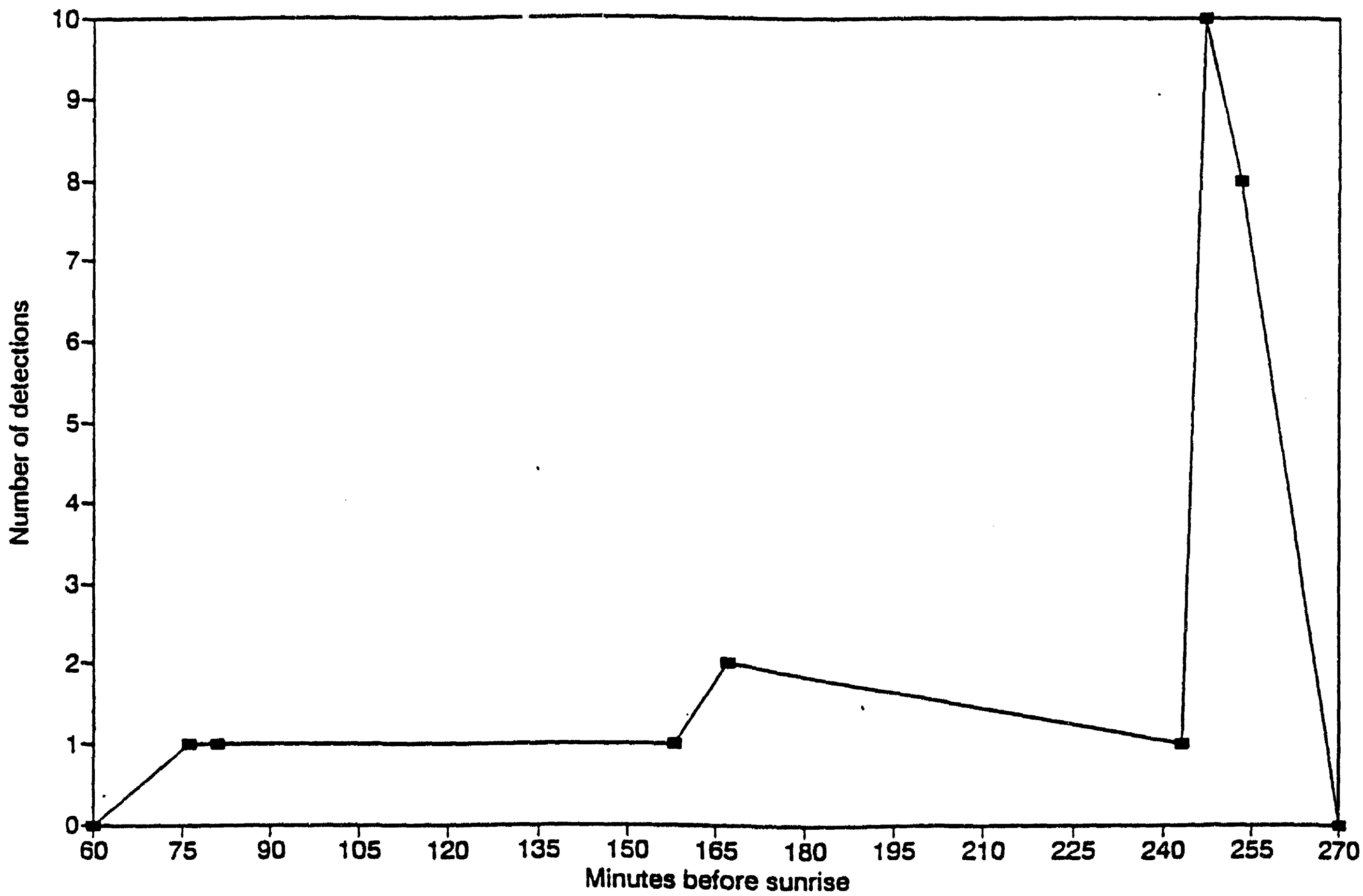

Figure 8. Morning activity pattern of Newell's shearwaters at two colony sites in Puna. Detection times are based on vocalizations heard between July and October 1993.

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